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Kitamura

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(54) **FUEL INJECTION VALVE**

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(52) **U.S. Cl.** **239/533.12**; 239/533.11; 239/533.2; 239/533.14; 239/585.1; 239/596

(58) **Field of Search** 239/494, 533.1, 239/533.2, 533.3, 533.11, 533.12, 533.14, 533.15, 585.1, 585.2, 585.3, 585.4, 585.5, 596

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(57) **ABSTRACT**

In a fuel injection valve including a flat fuel diffusion chamber provided between a valve seat member and an injector plate to widen radially outwards from an outer end edge of a valve seat bore, an annular step is formed on a ceiling surface of the fuel diffusion chamber so that a level of the ceiling surface is gradually lowered radially outwards, and fuel injection orifices are disposed immediately below the step and at a distance from an inner peripheral wall of the fuel diffusion chamber. Thus, a fuel spread radially in the fuel diffusion chamber is allowed to collide with the annular step, leading to an enhancement in fuel diffusing effect, so that it is possible to further promote the atomization of the fuel injected from the fuel injection orifices and to form more stable fuel spray forms.

4 Claims, 6 Drawing Sheets

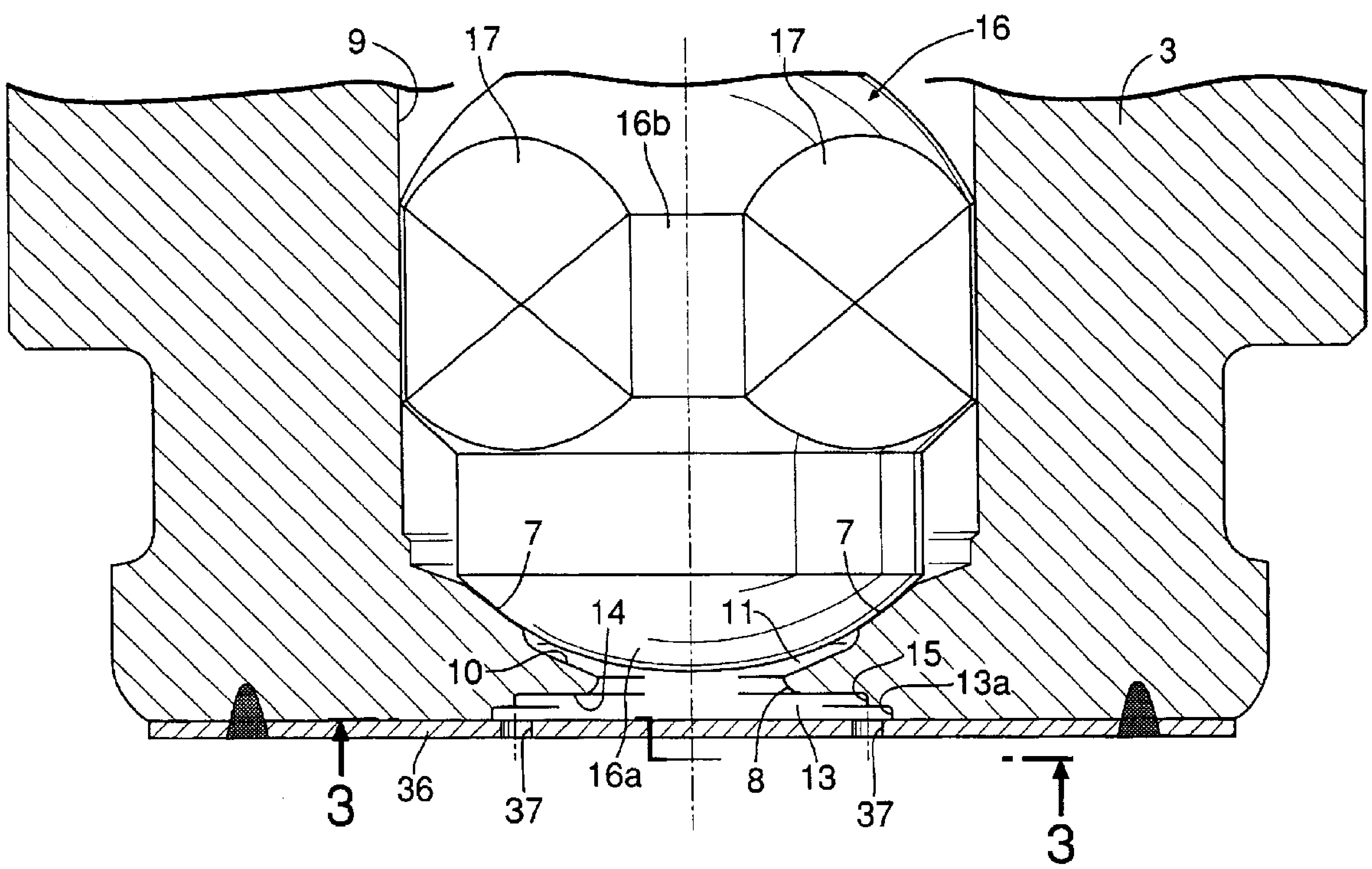

FIG.1

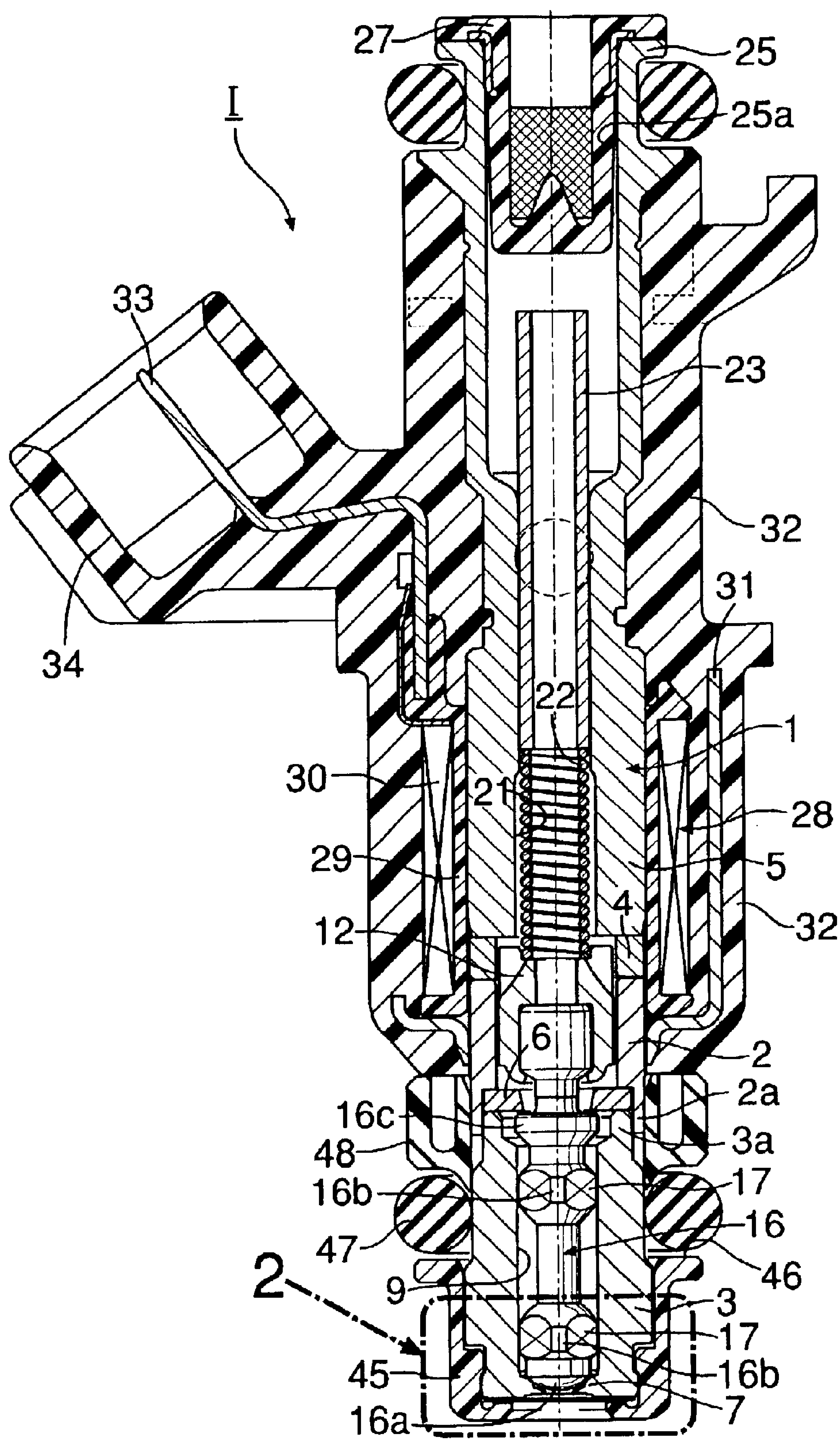
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FIG.2

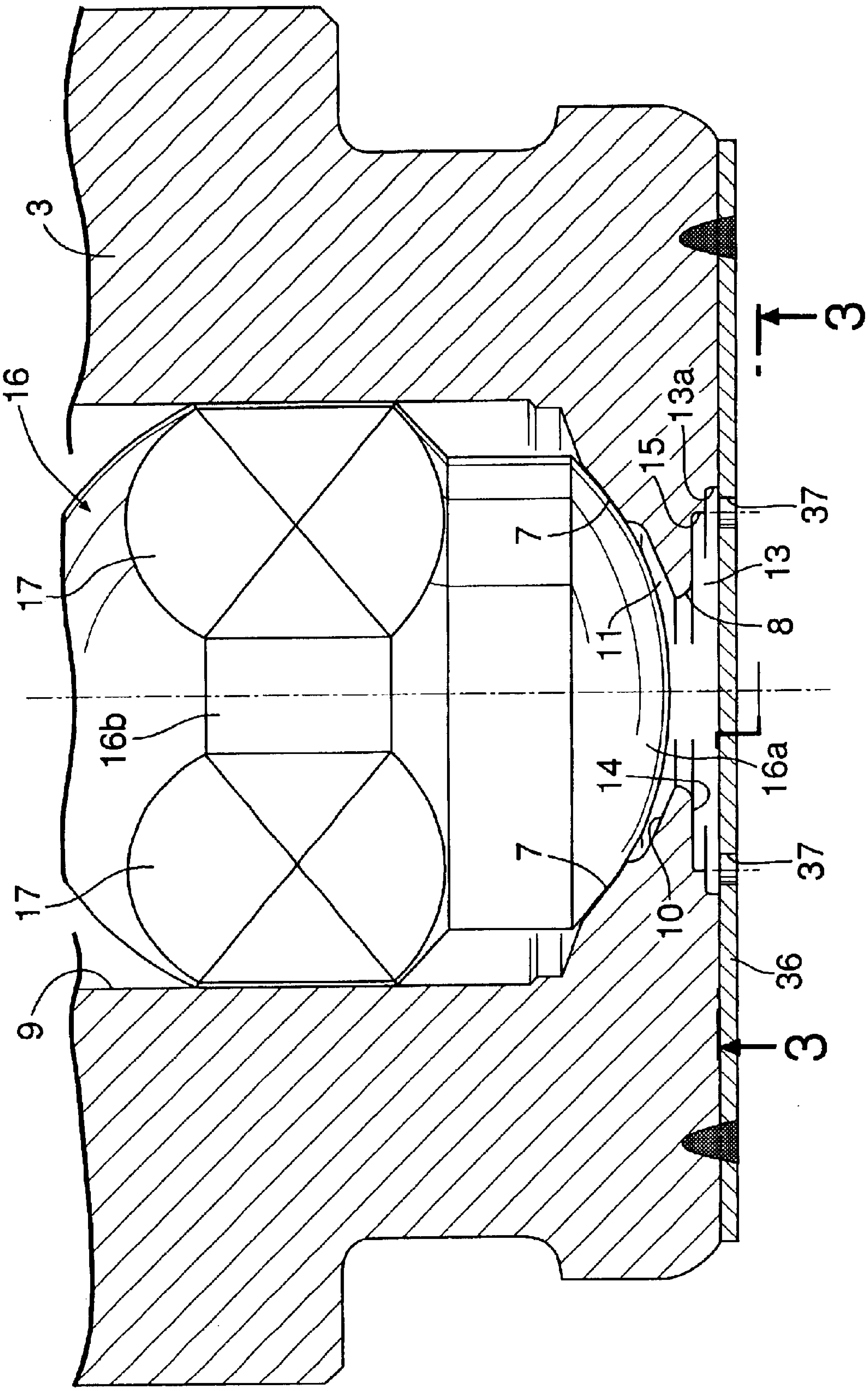


FIG.3

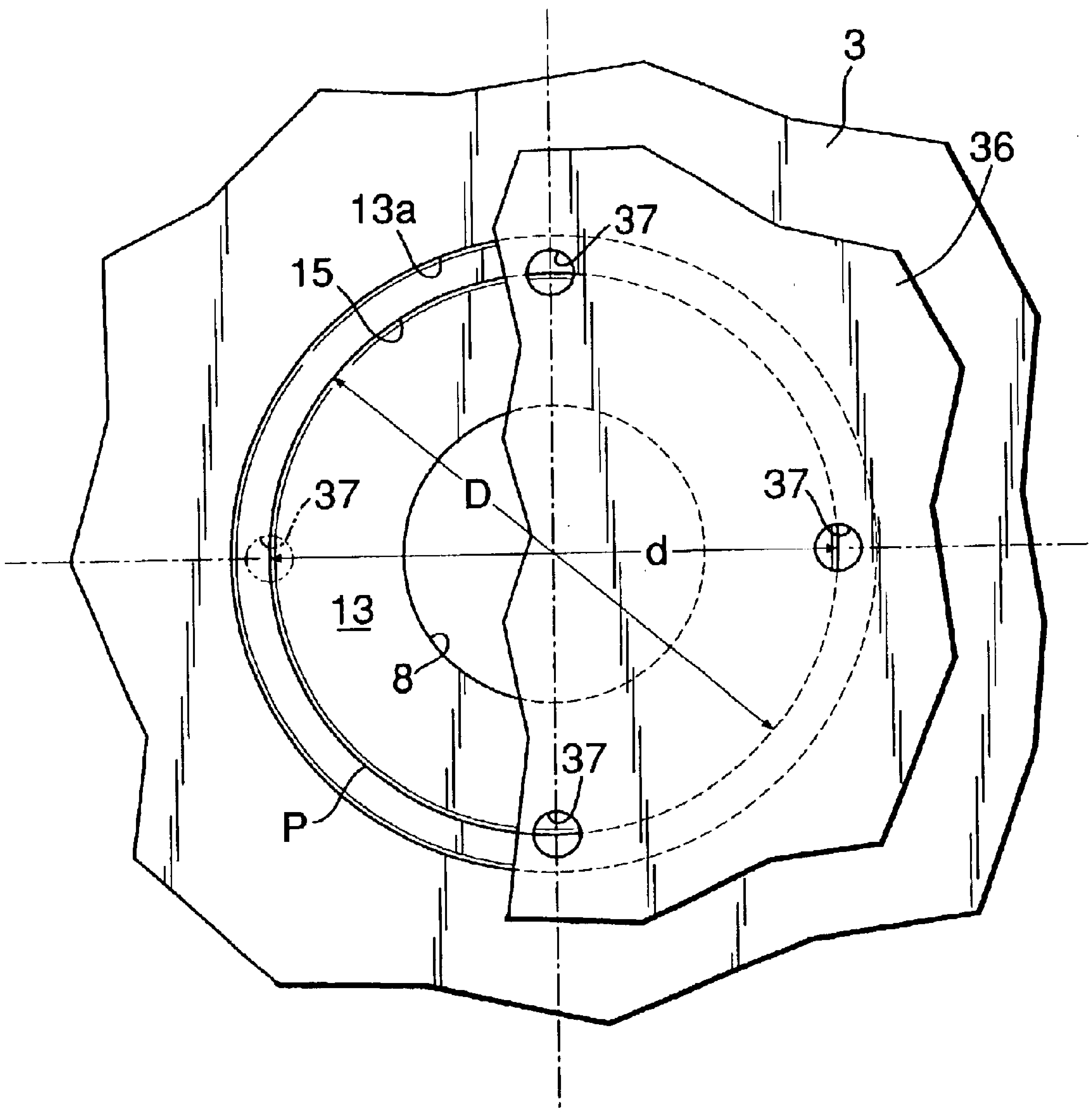


FIG.4

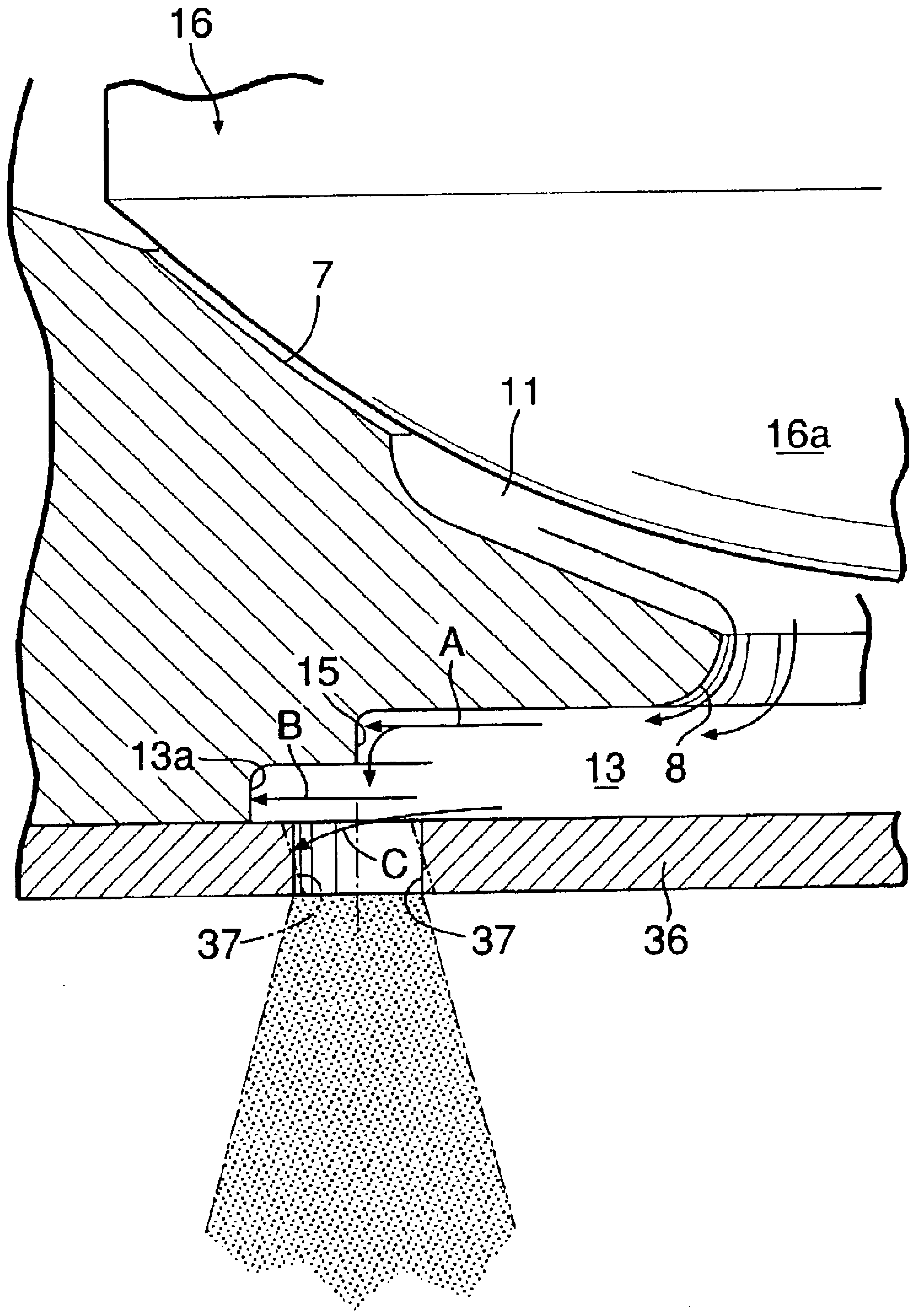


FIG.5

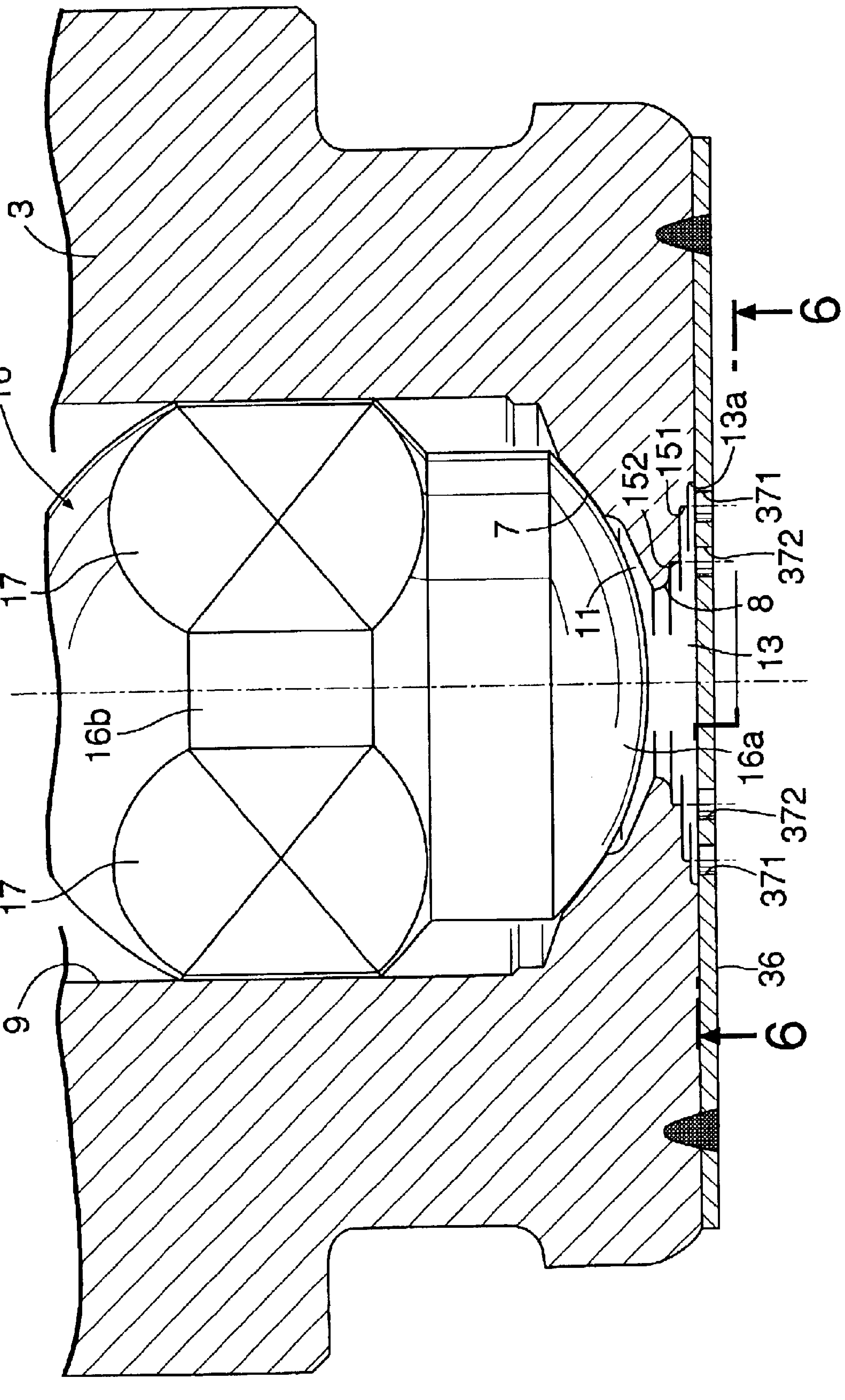
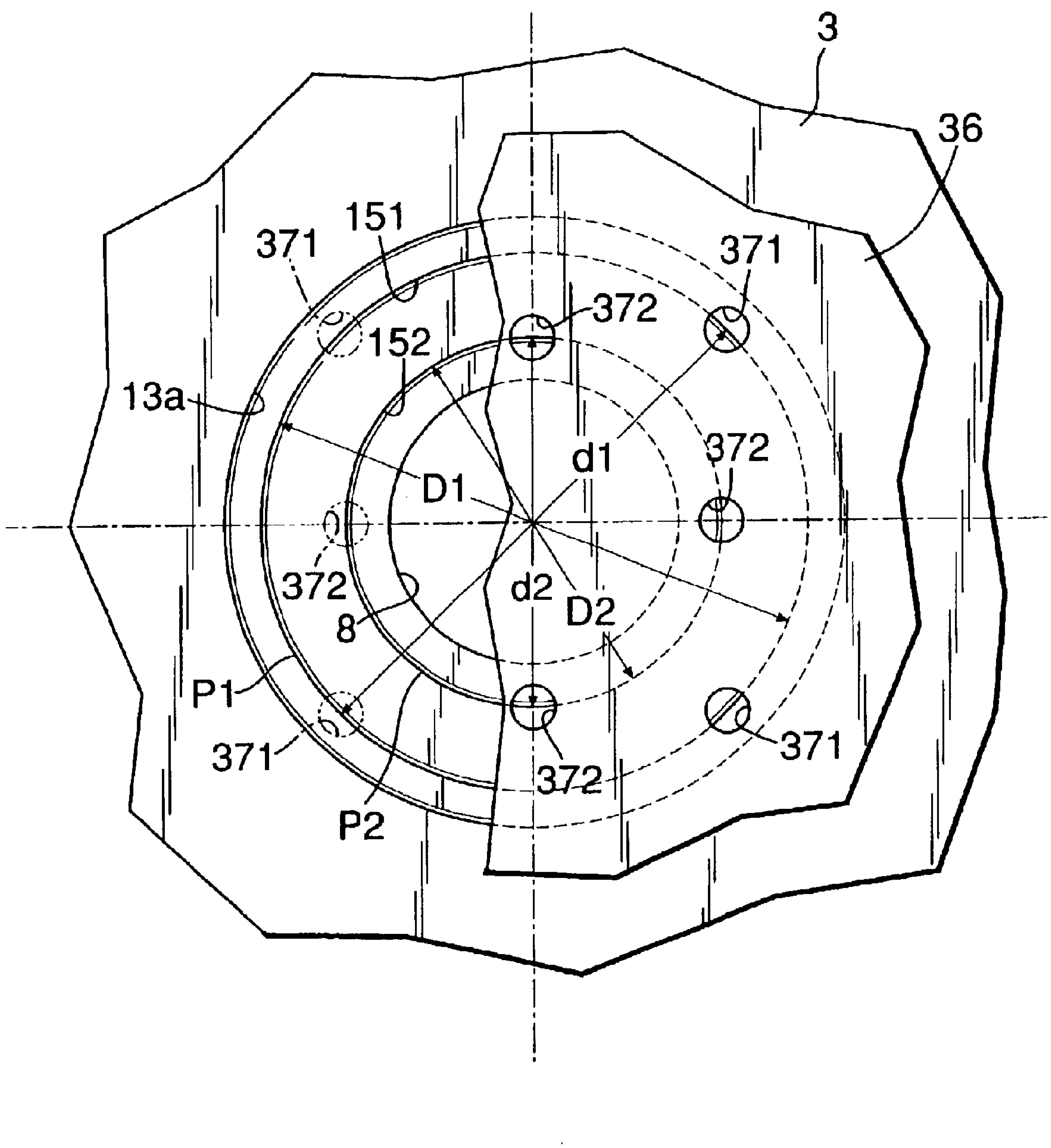


FIG.6



FUEL INJECTION VALVE

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a fuel injection valve used mainly in a fuel supply system for an internal combustion engine, and particularly to an improvement in a fuel injection valve comprising: a valve member; a valve seat member which has a valve seat cooperating with said valve member, and a valve seat bore leading to a downstream end of said valve seat and opening at a front end face said valve seat member; an injector plate coupled to the front end face of said valve seat member and having a plurality of fuel injection orifices; and a flat fuel diffusion chamber provided between said valve seat member and said injector plate to widen radially outwards from an outer end edge of said valve seat bore for dispensing a fuel received therein from said valve seat bore to the plurality of fuel injection orifices in a diffusing manner.

2. Description of the Related Art

A conventional fuel injection valve is already known, as disclosed in, for example, Japanese Patent Application Laid-open No. 2000-97129.

The conventional injection valve has the following advantage: During opening of the valve member, a high-pressure fuel passed through the valve seat is allowed to flow at a high speed into the fuel diffusion chamber to be diffused, thereby promoting the atomization of the fuel injected from each of the fuel injection orifices in the injector plate and forming stable fuel spray forms.

SUMMARY OF THE INVENTION

Accordingly, it is an object of the present invention to provide a fuel injection valve, wherein the fuel-diffusing function of the fuel diffusion chamber can be further enhanced, to thereby further promote the atomization of the fuel injected from the fuel injection orifices and to form more stable fuel spray forms.

To achieve the above object, according to a first feature of the present invention, there is provided a fuel injection valve comprising: a valve member; a valve seat member which has a valve seat cooperating with said valve member, and a valve seat bore leading to a downstream end of said valve seat and opening at a front end face said valve seat member; an injector plate coupled to the front end face of said valve seat member and having a plurality of fuel injection orifices; and a flat fuel diffusion chamber provided between said valve seat member and said injector plate to widen radially outwards from an outer end edge of said valve seat bore for dispensing a fuel received therein from said valve seat bore to the plurality of fuel injection orifices in a diffusing manner; wherein an annular step is formed on a ceiling surface of said fuel diffusion chamber so that a level of the ceiling surface is gradually lowered radially outwards, and said fuel injection orifices are disposed immediately below said step and at a distance from an inner peripheral wall of said fuel diffusion chamber.

With the first feature, during opening of the valve member, the fuel transferred from the valve seat bore into the flat fuel diffusion chamber flows to spread radially. Thereafter, the fuel flowing along the ceiling surface of the fuel diffusion chamber collides with the annular step to be scattered to the periphery, and the flow flowing along a bottom surface of the fuel diffusion chamber collides with

the inner peripheral wall of the chamber to be scattered while being bounced back therefrom. The scattered fuel portions again collide with one another immediately above the plurality of fuel injection orifices, whereby the fierce turbulent flow and diffusion of the fuel are caused. As a result, the atomization of the fuel injected from the fuel injection orifices can be effectively promoted, and stable fuel spray forms can be formed and drawn into the engine along with intake air, while being prevented from being deposited to an inner wall of an intake passage for the engine to the utmost. Thus, it is possible to provide enhancements in startability and output performance of the engine as well as a reduction in fuel consumption.

According to a second feature of the present invention, in addition to the first feature, a diameter of a pitch circle of the plurality of fuel injection orifices is equal to a diameter of the annular step.

With the second feature, the fuel turbulent flow generated in the fuel diffusion chamber can be injected with a good efficiently from the fuel injection orifices, thereby effectively promoting the atomization of the fuel.

According to a third feature of the present invention, in addition to the first or second feature, the valve seat bore is formed into a funnel-shape having a diameter increasing toward the fuel diffusion chamber.

With the third feature, the flowing of the fuel from the valve seat bore into the fuel diffusion chamber can be smoothened, whereby a high speed of collision of the fuel with the annular step can be maintained, and the atomization of the fuel injected from the fuel injection orifices can be promoted.

According to a fourth feature of the present invention, in addition to the first or second feature, a plurality of the annular steps having different diameters are formed in a stair-shape on the ceiling surface of the fuel diffusion chamber, and a plurality of the fuel injection orifices are disposed on each of a plurality of pitch circles having different diameters in correspondence to the annular steps, respectively.

With the fourth feature, the fuel transferred from the valve seat bore into the fuel diffusion chamber collides sequentially with the stair-shaped annular steps and the inner peripheral wall of the fuel diffusion chamber, whereby more fierce turbulent flow and diffusion of the fuel are caused, so that the atomization of the fuel injected from the fuel injection orifices can be further effectively promoted.

The above and other objects, features and advantages of the invention will become apparent from the following description of the preferred embodiments taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a vertical sectional view of a solenoid-type fuel injection valve for an internal combustion engine according to a first embodiment of the present invention;

FIG. **2** is an enlarged view of a portion indicated by **2** in FIG. **1**;

FIG. **3** is a sectional view taken along a line **3**—**3** in FIG. **2**;

FIG. **4** is an enlarged view of essential portions of FIG. **2** for explaining the operation;

FIG. **5** is a view similar to FIG. **2**, but showing a second embodiment of the present invention; and

FIG. **6** is an enlarged sectional view taken along a line **6**—**6** in FIG. **5**.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

A first embodiment of the present invention will first be described with reference to FIGS. **1** to **4**.

Referring to FIG. **1**, a casing **1** of a solenoid-type electromagnetic fuel injection valve I for an internal combustion engine is comprised of a cylindrical valve housing **2** (made of a magnetic material), a bottomed cylindrical valve seat member **3** liquid-tightly coupled to a front end of the valve housing **2**, and a cylindrical core **5** liquid-tightly coupled to a rear end of the valve housing **2** with an annular spacer **4** interposed therebetween.

The annular spacer **4** is made of a non-magnetic metal such as stainless steel, and the valve housing **2** and the stationary core **5** are butted against and liquid-tightly welded to opposite end faces of the annular spacer **4** over the entire periphery.

A first fitting tube **3***a* and a second fitting tube **2***a* are formed on opposed end faces of the valve seat member **3** and the valve housing **2**, respectively. The first fitting tube **3***a* is press-fitted into the second fitting tube **2***a* along with a stopper plate **6**, which is clamped between the valve housing **2** and the valve seat member **3**. Thereafter, the valve housing **2** and the valve seat member **3** are liquid-tightly coupled to each other by a laser welding or beam welding carried out over the entire periphery of a corner sandwiched between an outer periphery surface of the first fitting tube **3***a* and an end face of the second fitting tube **2***a*.

The valve seat member **3** is provided at its front end face with a conical valve seat **7** which opens at its downstream end, and a cylindrical guide bore **9** connected to an upstream end, i.e., a larger-diameter portion of the valve seat **7**. The guide bore **9** is formed coaxially with the second fitting tube **2***a*.

A movable core **12** is slidably received in the valve housing **2** and the annular space **4** and opposed to a front end of the stationary core **5**. A valve member **16** axially slidably received in the guide bore **9** is integrally coupled to the movable core **12**. The valve member **16** is integrally provided with a spherical valve portion **16***a* capable of being seated on the valve seat **7**, a pair of front and rear journal portions **16***b*, **16***b* slidably carried in the guide bore **9**, and a flange **16***c* adapted to abut against the stopper plate **6** to define an opening limit for the valve member **16**. A plurality of chamfers **17** are provided on each of the journal portions **16***b* to enable the flowing of a fuel.

The stationary core **5** has a hollow **21** communicating with the interior of the valve housing **2**. The hollow **21** accommodates a coil-shaped valve spring **22** for biasing the movable core **12** in a direction to close the valve member **16**, i.e., toward a direction to seat on the valve seat **7**, and a pipe-shaped retainer **23** for supporting a rear end of the valve spring **22**.

An inlet tube **25** is integrally connected to a rear end of the stationary core **5**, and has a fuel inlet **25***a* communicating with the hollow **21** in the stationary core **5** through the pipe-shaped retainer **23**. A fuel filter **27** is mounted in the fuel inlet **25***a*.

A coil assembly **28** is fitted over outer peripheries of the annular spacer **4** and the stationary core **5**. The coil assembly **28** comprises a bobbin **29** fitted over the outer peripheries of the annular spacer **4** and the stationary core **5**, and a coil **30** wound around the bobbin **29**. One end of a coil housing **31** surrounding the coil assembly **28** is coupled by welding to an outer peripheral surface of the valve housing **2**.

The coil housing **31**, the coil assembly **28** and the stationary core **5** are embedded in a cover **32** made of a synthetic resin. A coupler **34** is integrally connected to an intermediate portion of the cover **32**, and accommodates a connecting terminal **33** leading to the coil **30**.

As shown in FIGS. **2** to **4**, a front end wall of the valve seat member **3** is provided with a valve seat bore **8** arranged coaxially with the valve seat **7** at a location downstream from the valve seat **7**, and a recess **10** which connects the valve seat bore **8** and the valve seat **7** to each other. The recess **10** defines a preliminary diffusion chamber **11** by cooperation with a tip end face of the valve portion **16***a*.

An injector plate **36** made of a steel pate is bonded to the front end face of the valve seat member **3** over the entire periphery by a laser beam welding. A plurality of fuel injection orifices **37** are provided in the injector plate **36** on a pitch circle P about an axis of the valve seat **7**. A fuel diffusion chamber **13** is provided between the valve seat member **3** and the injector plate **36** to allow the valve seat bore **8** to communicate with the fuel injection orifices **37**. In the illustrated embodiment, the fuel diffusion chamber **13** is defined by a flat recess **14** widening radially outwards from an outer end edge of the valve seat bore **8**, and an upper surface of the injection plate **36**. Each of the fuel injection orifices **37** is disposed so that its axis is parallel to an axis of the valve seat bore **8** (shown by a solid line in FIG. **4**), or is nearing the axis of the valve seat bore **8** in an axially outward direction (shown by a dashed line in FIG. **4**).

An annular step **15** is formed on a ceiling surface of the fuel diffusion chamber **13** so that its height is reduced gradually radially outwards, and the plurality of fuel injection orifices **37** are disposed immediately below the step **15**. In this case, the pitch circle P passing through a center of each of the plurality of fuel injection orifices **37** has a diameter d set at a value equal to a diameter D of the annular step **15**, whereby the center of each of the fuel injection orifices **37** is disposed substantially immediately below the annular step **15**. Further, the fuel injection orifices **37** are disposed at locations spaced at a given distance apart from an inner peripheral wall **13***a* of the fuel diffusion chamber **13**.

The valve seat bore **8** is formed into a funnel-shape increased in diameter toward the fuel diffusion chamber **13**.

Referring again to FIG. **1**, an annular seal holder **48** is fitted over the outer peripheries of the valve housing **2** and the valve seat member **3** to extend astride them. An annular groove **46** is defined between the seal holder **48** and a cap **45** made of a synthetic resin and fitted over the front end of the valve seat member **3**. An O-ring **47** is mounted in the annular groove **46** to come into close contact with the outer peripheral surface of the valve seat member **3**. The O-ring **47** is adapted to come into close contact with an inner peripheral surface of a fuel-injection-valve mounting bore in an intake manifold (not shown), when the solenoid-type fuel injection valve I is mounted in the mounting bore.

The operation of the first embodiment will be described below.

In a state in which the coil **30** has been deexcited, the movable core **12** and the valve member **16** are urged forwards by a biasing force of the valve spring **22**, whereby the valve portion **16***a* of the valve member **16** is seated on the valve seat **7**. Therefore, a high-pressure fuel supplied through the fuel filter **27** and the inlet tube **26** into the valve housing **2** is left on standby within the valve housing **2**.

When the coil **30** is excited by supplying electric current thereto, a magnetic flux generated thereby runs sequentially through the stationary core **5**, the coil housing **31**, the valve housing **2** and the movable core **12**, whereby the movable core **12** is attracted to the stationary core **5** along with the valve member **16** by a magnetic force to open the valve seat **7**. Therefore, the high-pressure fuel in the valve housing **2** passes the chamfers **17** of the valve member **16** and the valve seat **7**, and then passes the preliminary diffusion chamber **11** and the valve seat bore **8** into the fuel diffusion chamber **13**. Finally, the fuel is injected from the plurality of the fuel injection orifices **37** into an intake port in the internal combustion engine (not shown).

As best shown in FIG. **4**, the fuel transferred from the valve seat bore **8** into the flat fuel diffusion chamber **13** flows to radially spread. Thereafter, the fuel A flowing along the ceiling surface of the fuel diffusion chamber **13** collides with the annular step **15** to be scattered to the periphery, and the fuel B flowing along the bottom surface of the fuel diffusion chamber **13** collides with the inner peripheral wall **13***a* of the chamber **13** to be scattered while being bounced back from the inner peripheral wall **13***a*. The scattered fuel portions again collide with one another immediately above the plurality of fuel injection orifices **37**, thereby causing a fierce turbulent flow and diffusion of the fuel. Therefore, the atomization of the fuel injected from the fuel injection orifices **37** is effectively promoted, whereby the stable spray forms of the fuel can be formed and drawn into the engine along with intake air. Thus, it is possible to provide enhancements in startability and output performance of the engine as well as a reduction in fuel consumption.

In addition, since the valve seat bore **8** is formed into the funnel-shape having a diameter increasing toward the fuel diffusion chamber **13**, the flowing of the fuel from the valve seat bore **8** into the fuel diffusion chamber **13** can be smoothened, whereby a high speed of collision of the fuel with the annular step **15** can be maintained, thereby contributing to the atomization of the fuel injected from the fuel injection orifices **37** and the formation of the stable spray forms.

Further, the fuel flowing from the valve seat bore **8** along the bottom surface of the fuel diffusion chamber **13** includes a portion C immediately takes a course bent in a direction toward the fuel injection orifices **37**. The fuel portion having taken the course toward the fuel injection orifices **37** collides with the inner surface of each of the fuel injection orifices **37** at a substantially right angle to thereby cause a fierce turbulent flow, because the axis of each of the fuel injection orifices **37** is parallel to the axis of the valve seat bore **8**, or is inclined so that it is nearing the axis of the valve seat bore **8** in an axially outward direction. Thus, when such fuel is injected from the fuel injection orifices **37**, it can be peeled off from the surface of the injector plate **36**. This also contributes to the promotion of the atomization of the fuel and the formation of the stable spray forms.

A second embodiment of the present invention will now be described with reference to FIGS. **5** and **6**.

In the second embodiment, a plurality of (two in the illustrated embodiment) annular steps **151** and **152** having different diameters D1 and D2 are formed concentrically and in a stair-shape on a ceiling surface of the fuel diffusion chamber **13**. A plurality of fuel injection orifices **371** is disposed immediately below the larger diameter-annular step **151** on a pitch circle **P1** having a diameter d1 equal to the diameter D1 of the larger-diameter annular step **151**. A plurality of fuel injection orifices **372** is disposed immediately below the smaller-diameter annular step **152** on a pitch circle P2 having a diameter d2 equal to the diameter D2 of the smaller-diameter annular step **152**. The fuel injection orifices **371** and **372** are disposed with their phases displaced from each other. The arrangement of the other components is the same as that in the previous embodiment. Hence, the portions or components corresponding to those in the previous embodiment are designated by the same reference numerals and symbols in FIGS. **5** and **6** and the description of them is omitted.

In the second embodiment, the fuel transferred from the valve seat bore **8** into the fuel diffusion chamber **13** collides sequentially with the plurality of stages of the larger and smaller annular steps **151** and **152** and the inner peripheral wall of the fuel diffusion chamber **13**, whereby the turbulent flow and diffusion of the fuel are further fiercely caused. Thus, it is possible to further effectively promote the atomization of the fuel injected from each of the fuel injection orifices **371** and **372** and to form further stable spray forms of the fuel.

It will be understood that the present invention is not limited to the above-described embodiments, and various modifications in design may be made without departing from the spirit and scope of the invention defined in claims.

What is claimed is:

1. A fuel injection valve comprising: a valve member; a valve seat member which has a valve seat cooperating with said valve member, and a valve seat bore leading to a downstream end of said valve seat and opening at a front end face said valve seat member; an injector plate coupled to the front end face of said valve seat member and having a plurality of fuel injection orifices; and a flat fuel diffusion chamber provided between said valve seat member and said injector plate to widen radially outwards from an outer end edge of said valve seat bore for dispensing a fuel received therein from said valve seat bore to the plurality of fuel injection orifices in a diffusing manner;

wherein an annular step is formed on a ceiling surface of said fuel diffusion chamber so that a level of the ceiling surface is gradually lowered radially outwards, and said fuel injection orifices are disposed immediately below said step and at a distance from an inner peripheral wall of said fuel diffusion chamber.

2. A fuel injection valve according to claim **1**, wherein a diameter of a pitch circle of the plurality of fuel injection orifices is equal to a diameter of said annular step.

3. A fuel injection valve according to claim **1** or **2**, wherein said valve seat bore is formed into a funnel-shape having a diameter increasing toward said fuel diffusion chamber.

4. A fuel injection valve according to claim **1** or **2**, wherein a plurality of the annular steps having different diameters are formed in a stair-shape on the ceiling surface of said fuel diffusion chamber, and a plurality of the fuel injection orifices are disposed on each of a plurality of pitch circles having different diameters in correspondence to said annular steps, respectively.

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